Objective Verification of Digital Hearing Aid Functions and Settings for Individual Patients

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The Case of a Woman Perpetually Falling
Redesigning The Brain
Inspiring Stories of Cortical Neural Plasticity
The “Fundamentals”

- The goal of amplification is to restore speech audibility
  - The focus of the fitting process to make this happen, and to verify it
- Gain is a tool used to restore audibility, but its presence does not verify that audibility has been restored
The “Fundamentals”

- Dynamic amplification can only be effectively evaluated in the presence of dynamic stimulation.
- Amplification addresses only the peripheral aspects of audibility.
- Maximized speech audibility is not appropriate for all peripheral hearing losses.
The “Fundamentals”

- Normed “targets” are not always “audibility-targets”
- Objective verification of hearing aid utility is superior to subjective opinions
Modern Objective Wisdom: Measure the Audibility of Speech Directly

- Traditional REM Wisdom
  - Input Stimulus
    - PT sweep
    - Noise
  - Measure REIG curve
  - Adjust gain to hit a predicted insertion GAIN target

- Modern On-Ear Wisdom
  - Input Stimulus
    - Speech
    - “Dynamics”
  - Measure REAR speech banana
  - Adjust gain AND compression to deliver AUDIBILITY to THIS patient
The Basic Speechmap Screen

Connect coupler and instrument to coupler microphone. Select one of Test 1 through Test 4.
The Aided Speech Banana
Why Output Instead of Gain?
For this compression hearing aid...

Gain for speech ≈ Gain for tones

GAIN FOR 70 dB SPEECH & 70 dB TONE. K-AMP. MODERATE LOSS

Gain for speech
Gain for tones
Output for speech is much less than output for pure tones.
Speech Is An Excellent WDRC Measurement Stimulus

- It IS the most important input signal that the patient will want to hear well and comfortably
- It interacts with multi-band compressors in a more realistic way than tones
  - band interactions across frequency
  - changing intensity
The difference in dB across frequencies between the SPL measured in the real-ear and in a 2cc coupler, produced by a transducer generating the same input signal.
RECD Measurement

How is it done?

- Composed of 2 measurements: 2cc coupler measurement and real-ear measurement.

1) Recruitment Accommodation
How do we measure RECD?

Measuring the coupler response of the insert earphone

COUPLER MICROPHONE

BTE COUPLER

RE770 TRANSDUCER

Graph showing dB levels across different frequencies.

250 500 1k 2k 4k 8k
Measuring the real-ear response of the insert earphone..

Real-ear response

Coupler response

Average RECD

RECD
The Verifit uses the RECD to...

- Convert threshold and UCL obtained using insert earphones to SPL near the TM
- Convert test box measurements of hearing aid output to estimated real-ear aided response

1) Recruitment

Accommodation
RECD: Things to Remember

- Measured RECD is only applied if “Insert-Foam” has been selected as the transducer.
- Measured RECD is only valid if it is measured as described in the manual (i.e. with the foam tip).
Speechmap Fitting Protocol

- Test 1:
  - Input: 50dB STD speech
  - Goal: To adjust the gain of the aid so that at least the middle line of the aided speech banana hovers above the SPL threshold line
Test 1 Result

Viewport/Test box

Audibility verification using Speechmap

Test Stimulus Level SII
1 Speech-std(1) Soft (50) 53
2 Soft (65)
3 Soft (65)

Unaided (65) 33

Curve Hide / Show

Select one of Test 1 through Test 3.
Speechmap Fitting Protocol

- Test 2:
  - Input: 65dB STD speech
  - Goal: To verify that the bottom line of the aided speech banana is just above threshold
    - Use compression settings to adjust the width of the banana
Test 2 Result
Speechmap Fitting Protocol

- Test 3:
  - Input: MPO Sweep
  - Goal: To adjust the MPO of the aid so that the blue dots come as close as possible to the UCL asterisks without being above them
Select one of Test 1 through Test 3.
The Counseling Screen
**17 Speechmap**

The speech recognition associated with a given SII is a function of the test material and the cognitive abilities of the listener. There is considerable individual variability in relating the SII to speech recognition, especially amongst impaired listeners. The following shows expected nominal recognition scores vs SII for normals on the Connected Speech Test (Sherbecoe and Studebaker 2003).

<table>
<thead>
<tr>
<th>SII (%)</th>
<th>Score (%)</th>
</tr>
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<tbody>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
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<td>30</td>
<td>60</td>
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<td>35</td>
<td>74</td>
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<td>40</td>
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</tr>
<tr>
<td>60</td>
<td>98</td>
</tr>
<tr>
<td>70</td>
<td>99</td>
</tr>
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</table>

Score for Connected Speech Test vs SII
What Does the Speechmap Protocol Provide You?

- **Verification** that soft speech energy is audible to the patient
- **Verification** that average speech energy is comfortably positioned within the patient's audible range
- **Verification** that UCL levels can not be exceeded, regardless of stimulus type
- **Verification** that the patient's recruitment has been accommodated
Recruitment Accommodation Clinical Protocol

- At initial assessment visit:
  - Obtain RECD measurement
- Prior to fitting visit
  - Program aid and do Speechmap protocol in Test-Box mode
- At fitting visit
  - Do Speechmap protocol in On-Ear mode
Cochlear Dead Regions

- Regions in cochlea were inner hair cells and/or neurons are effectively not functioning at all
- Vary considerably from person to person
- Most often located toward the basal end of the basilar membrane
How Common Are Dead Regions?

<table>
<thead>
<tr>
<th>For HL thresholds</th>
<th>The likelihood of dead regions is</th>
</tr>
</thead>
<tbody>
<tr>
<td>55dB or less</td>
<td>Rare</td>
</tr>
<tr>
<td>55dB to 75dB</td>
<td>Possible</td>
</tr>
<tr>
<td>Greater than 75dB</td>
<td>Increasingly Common</td>
</tr>
</tbody>
</table>
Dead Region “Audibility”

“Off Frequency” Listening
Is high-frequency amplification always beneficial?

from Hogan & Turner, JASA 1998
The TEN Test

- Threshold-Equalizing Noise (TEN) Test
  - A masked threshold is approximately equal to the nominal level of the TEN noise stimulus
    - 70dB noise should produce app. 70dB threshold at all test frequencies
  - A masked threshold that is at least 10dB higher than normal is POSITIVE for a cochlear dead region

Verifying Digital Performance

Verifying Frequency Lowering and Frequency Transposition Functions
The Concept Behind Changing Output Frequency Content

- Some hearing losses have un-aidable regions where important speech information exists.
- Re-positioning input energy in these regions to regions that are aidable can provide access to these important speech questions.
The Solution: Frequency Shifting

- For many people with severe-to-profound hearing impairment in the higher frequencies, frequency shifting can improve signal audibility.
- Numerous different frequency lowering schemes have been developed and evaluated.
- Some of these schemes have been shown to improve speech understanding.

Hugh McDermott, Professor of Auditory Communication and Signal Processing
University of Melbourne, Phonak Virtual Audiology Conference, May, 2009
Practical frequency-shifting techniques
Frequency Shifting Approaches

- Frequency Transposition

Myirel Nyffeler, Speech Study Coordinator, Phonak Hearing Instruments, Switzerland, Phonak Virtual Audiology Conference, May, 2009
Frequency Shifting Approaches

- Frequency Transposition
Widex *Inteo* 'Audibility Extender'

SOURCE OCTAVE

TARGET OCTAVE

SHIFT AND OVERLAP (MIX)
Widex AE - continued

FILTER OUTPUT SIGNAL ‘TO LIMIT MASKING EFFECT’

OUTPUT SPECTRUM:

INPUT SPECTRUM:
Frequency Shifting Approaches

- Frequency Compression
Frequency Shifting Approaches

- Frequency Compression
Effect of parameters when processing /aSa/

Lower cut-off frequencies = stronger frequency compression
Software Release
V3.4

- Main New Features
  - Frequency Lowering Verification
Frequency Lowering Input Stimuli

LTASS Speech-std(1)
LTASS Speech4000
LTASS Speech5000
LTASS Speech6300
Frequency Lowering Test Result Example

Aided Speech-std(1)
6300Hz not audible

Aided Speech6300
Frequency lowering OFF
6300Hz still not audible

Aided Speech6300
Frequency lowering ON
6300Hz now audible @
4000Hz-region
Speech Mapping of Open-Fit (Thin-Tube) Technology
Minimal Occlusion

FIGURE 5: The pink shaded area is the eardrum SPL “speech banana” for 65dB speech input measured at the probe tip with the open-fit hearing aid turned OFF. The green shaded area is the eardrum SPL “speech banana” with the same hearing aid turned ON. The difference between the two indicates where amplification has reached the eardrum.
Verifying Digital Performance

2) Verifying Directionality Function
Laboratory Specification of Directionality

Polar Plots

2) Directional Verification
Conventional Directional Microphone Test
(Polar Plot Measurement)
Issues Associated with Conventional Polar Plot Testing

- Polar plots are obtained in the presence of a single pure tone frequency
- Polar plots do not measure in the presence of multiple input sources
- Polar plots cannot be obtained in the presence of non-linear (compression) amplification
A New Way of Measuring Directional Microphone Performance

Obtaining a Directional Microphone Frequency Response in the Presence of Multiple Input Source Locations
Viewport: Digital Functions Summary/ Test Protocol Screen

Contains both “Test Box” and “On Ear” Options

4 quadrants – one for each of the 4 digital functions tests

Pre-set (but adjustable) protocols
Viewport Directional Test Quadrant - Open
Verifit Testing System Hardware

Main Signal Source

Coupler Chamber

Secondary Signal Source
Recommended Hearing Aid Positioning In Test Box

Main Speaker

Secondary Speaker
Directional Frequency Response Input Stimulus

- Main input signal (512 pure tones 7.8Hz apart)
- Secondary input signal (512 pure tones 7.8 Hz apart)
Viewport Directional Test Box Result

Test box directional

<table>
<thead>
<tr>
<th>Test</th>
<th>Stimulus</th>
<th>Level Spkr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Speech</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Noise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>70</td>
</tr>
</tbody>
</table>

Select Test 1 or Test 2.
Directionality Test (REM)

Rear Facing Auxiliary Speaker

Subject

Aided Ear With Probe Tube Positioned

Verifit System In REM Directional Mode

2) Directional Verification
Open-Fit and Directional Mics

- Run “Directional” test in the box
- Compare directional frequency response separation in the aided frequency response region
- Curve separation in the aided region implies directional advantage available
  - Compare lower curve to “unaided” banana “noise-floor”
Verifying Digital Performance

3) Verifying Noise Reduction Function
Digital Noise Reduction Properties

- Digital algorithm programmed to recognize “non-speech” elements of incoming stimulus
  - Operates independently in bands
  - Analyzes incoming signal modulation

- Can vary in terms of time constants
  - Typically, slow attack, fast release
Viewport Noise Reduction
Test Box Quadrant - Open

Select Test 1 or Test 2.
Viewport Noise Reduction Test Result

Select Test 1 or Test 2.
Verifying Digital Performance

4) Verifying Feedback Reduction Function
<table>
<thead>
<tr>
<th>Phase Canceller</th>
<th>Notch Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Best Overall Application</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Passive</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Poorest Overall Application</strong></td>
</tr>
</tbody>
</table>
Key Factor of Concern

- Does the feedback suppression function compromise hearing instrument performance when processing other stimuli?
Interactive Feedback Reduction Measurement
Viewport Feedback Test Box Quadrant - Open
Expected Display When Feedback is Induced By Monitoring Headset

- Oscillation spikes
- 1/3 octave oscillation “humps”
Viewport Feedback
Box Test Result

Pink and green speech results overlap with phase cancellation
Viewport Final Results Screen

Viewport/Test box

Mar 28, 2008 9:37am

Audibility

Directional

Feedback

Noise reduction

Select a test.


References (cont.)


References (cont.)


Sound on Sound Recording Magazine, “Directional Microphones” September 2000 Issue, Cambridge, UK


References (cont.)


